CANADA/U.S. SPRUCE BUDWORMS PROGRAM--WEST

FINAL REPORT

Title: Field Evaluation of *Bacillus thuringiensis* and Baculovirus for Control of Western Spruce Budworm: Ground Application Trails

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Summary

Infestations of spruce budworm, Choristoneura occidentalis in three campgrounds along the Gallatin River south of Bozeman, Montana, were treated with ground applications of a microbial insecticide containing Bacillus thuringiensis. A truck-mounted hydraulic sprayer, operated at 300 to 350 psi, was used to apply the materials to infested Douglas-fir and Engelmann spruce trees up to 50 feet in height. Studies were designed to evaluate the effects of three factors, including host species (Douglas-fir vs. Engelmann spruce), dosage (16 vs. 32 VIU/100 gal.), and timing (early vs. late).

Treatment efficacy was assessed by: 1) measuring prespray and postspray larval density and computing population reduction (mortality) on treated vs. check trees, and 2) defoliation estimates on treated and check trees.

Generally the results showed budworm populations can be effectively controlled by ground applications of a tank mix containing 16 BIU/100 gal. of 5 percent molasses (v/v). This treatment also provided acceptable control of defoliation. Control of budworm larvae and feeding damage was not improved in tests of tank mixes containing 32 BIU/100 gal. Applications should be timed at peak fourth instar of budworm development for optimal results under the conditions of this trial.

Introduction

The western spruce budworm, *Choristoneura occidentalis*, periodically defoliates natural stands and ornamental plantings of true firs (*Abies* spp.), Douglas-fir, and spruce (*Abies* spp.). Outbreaks of budworm are often characterized by high population densities and feeding damage to new growth over prolonged periods of time, 3 to 5 years in duration. This prolonged feeding can result in outright tree mortality as well as losses in incremental growth and top- and branch-kill.

Tripp (1972) reported population reductions of 96 to 99 percent following aerial application of *Bacillus thuringiensis* (Bt) against the spruce budworm, *Choristoneura fumiferana*, on balsam fir. Aerial applications of Bt-chitinase in combination against the spruce budworm in the eastern U.S. and Canada provided good foliage protection (Dimond 1972, Smirnoff et al. 1973, Smirnoff 1974). While field efficacy of Bt was increased with the addition of small quantities of Orthene against moderate budworm densities, the combination did not provide satisfactory control against high population densities (Morris 1977). Thompson et al. (1977) reported that although significant reductions in *C. occidentalis* populations occurred following aerial applications of several Bt formulations, none of the treatments provided satisfactory population regulation.

In other tests mist blower applications of Bt in Canada failed to provide satisfactory foliage protection (DeBoo and Campbell 1974).

While microbial agents have undergone extensive testing, with mixed results, against eastern populations of spruce budworm, little or no information is available for spruce budworm under the greatly differing conditions of western forests. Host species are different in the West where populations are most critical on Douglas-fir, true fir species, and Engelmann spruce, in contrast to the balsam fir-white spruce host complex in eastern U.S. and Canada.

In recent years land managers have been concerned by the budworm infestations in high use recreational sites and campgrounds along the Gallatin River south of Bozeman, Montana. Proximity of the infestation to the river and heavy utilization of the area by campers greatly restricts or prohibits the use of chemical pesticides. These conditions present an ideal situation for controls based on a non-toxic microbial insecticide containing Bt. This study was designed to determine how the efficacy of Bt on spruce budworm is affected by: 1) timing of application, 2) tank mix concentration (dose), and 3) host tree species.

Materials and Methods

Thuricide 32B (32 X 10^9 international units/gal.), a flowable formulation of *B. thuringiensis*, was used in all of the trials. Tank mixes were prepared in water containing 5 percent (v/v) animal feed-grade molasses. Dosages of 16 and 32 BIU/100 gal. were tested on Douglas-fir (df) at Squaw Creek and on Engelmann spruce (es) at Swan Creek. A 3-factor factorial design was used at Red Cliff to compare differences in treatment response due to 1) host species (df vs. es), 2) dose (0 vs. 32 BIU/100 gal.), and 3) timing of application (early vs. late), and their interactions. The late timing was applied 6 days later than the early timing. Treatment combinations, including the untreated control, were assigned completely at random to 10 trees (replicates). Treatments were applied with a truck-mounted hydraulic sprayer up to the point of spray runoff. Approximately 8 to 10 gal. of spray provided adequate coverage of 30- to 50-ft. trees. Pump pressure ranged between 300 to 350 psi.

Evaluation

Measurements of the density of spruce budworm populations were made 1 to 4 hours before treatment and at 14 days after treatment. Trees showing high densities at 14 days were sampled again at 18 days to see if the response to Bt continued for a longer duration.

At each sampling interval, 15-inch branches were collected from midcrown of each sample tree (n = 2 prespray, n = 4 postspray). Counts of current year's shoots, the number of budworm larvae, and branch area were recorded. Population estimates were expressed as both the number of budworm larvae per 100 shoots and number of budworm larvae per 1,000 $in.^2$ branch area. At the completion of the larval feeding period, four 15-inch midcrown branches were collected for defoliation estimates. The method involved the examination of 25 shoots per branch. and classifying each shoot as to the amount of current foliage consumed or destroyed within 5 classes: 1 = 0; 2 = 1-25%; 3 = 26-50%; 4 = 51-75%; and 5 = 76-100%.

Analysis

Results were analyzed independently at each location. Spruce budworm prespray population density, 14-day population reductions (mortality), and defoliation data were subjected to analysis of variance. Covariance was used to adjust the 14-day mortality data at Squaw Creek and Swan Creek using prespray density as the covariate. No adjustments were made in 14-day mortality data at Red Cliff, or in the defoliation data, since prespray density as a covariate was not significant. Planned orthogonal single-degree of freedom contrasts at Swan Creek and Squaw Creek included 1) check vs. 16 + 32 BIU/100 gal., and 2) 16 vs. 32 BIU/100 gal.

The analyses of treatment parameters at Red Cliff were for a 3-factor factorial experiment with the degrees of freedom and sum of squares of treatment partitioned into the components attributable to main effects (specie, dose, and timing) and interactions.

Results and Discussion

Prespray density, 14-day population reductions (mortality), and defoliation data, for the three campgrounds, along with a summary of F values from the single degree of freedom contrasts at Squaw Creek and Swan Creek and the factorial analysis at Red Cliff, are presented in Tables 1 and 2.

Squaw Creek and Swan Creek Campgrounds. As would be expected the variation in the 14-day population reductions, on both the bud and area basis, was greater in the untreated check than in the treatments, resulting in a heterogeneous variance. Treatment means were still contrasted by analysis of covariance to look at the differences among the classes (0, 16, and 32 BIU/100 gal.). Since differences were so strikingly apparent (Table 1) it is felt that any biias resulting from failure to meet the assumption of homogeniety had minimal effect on these results (Table 2).

The two Bt treatments had significantly higher ($p \leq .01$) mortality at 14 days than on the check, but were not different from each other. An examination of the data shows differences

between bud and area mortalities were minimal. The population data confirm the defoliation data in that the high treatment mortalities provided significantly ($p \leq .01$) better foliage protection than the check.

Red Cliff Campground. Analysis of variance showed significant differences in mortality of budworm larvae on treated (95.2%) than on check (21.7%) trees, averaged over species and timing. Main effects for the species and the timing factors were not signficant. However, significant species X dose and species X timing interaction existed for changes in budworm mortality as determined by area density measurements (number sbw larvae/1,000 in.^{2} branch area). Figure 1 shows the nature of this interaction involved a change in direction of response with higher budworm mortality following the late timing on Engelmann spruce and the early timing on Douglas-fir.

Treatment with Bt provided significant foliage protection,[1/] ranging from 28.9% (late timing, Engelmann spruce) to 64.0% (early timing, Douglas-fir). Foliage protection, averaged over both timings, was 58.4% on Douglas-fir and 39.0% on Engelmann spruce. This result is related, at least in part, to the significantly higher prespray budworm densities on Engelmann spruce than on Douglas-fir (Table 1). Under the conditions of

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1/ Foliage protection = % defoliation on check trees - % defoliation on treated trees.

this study delaying treatment applications by 6 days, the difference between the early and late timings, resulted in increases in defoliation from 12.0 to 22.1% on Douglas-fir and from 24.8 to 39.2% on Engelmann spruce, respectively.

Conclusions

Spruce budworm populations, on Douglas-fir and Engelmann spruce, can be successfully controlled by ground applications of *Bacillus thuringiensis*. Treatment with *B. thuringiensis* also provided significant foliage protection, as compared to check trees where unacceptable levels of feeding took place.

Tank mixes containing 16 BIU/100 gal. were as effective as 32 BIU/100 gal in population control and foliage protection.

Applications timed at 6 days apart showed no difference in budworm mortality at 14 days after spraying, however, the delay did result in appreciable increase in level of defoliation.

Under conditions of very high budworm density, e.g. $\geq$ 100 larvae/1,000 in.^{2} branch area, treatment should be timed against peak fourth-instar to obtain maximum foliage protection.

Work Remaining on Study

This concludes my field experiments using ground applications of Bt against spruce budworm, *Choristoneura occidentalis*. Although two Baculovirus formulations were applied, budworm development was too advanced at the time of treatment to show any treatment response.

Cooperation and Coordination

I thank Larry Stipe (R-1, FIDM), and the staff at the Gallatin Ranger District, Bozeman, Montana, for their interest and support during this investigation. I am especially grateful for the laboratory space I was provided at the Squaw Creek Work Center, and to Larry Stipe for his assistance during spray applications and the postspray sampling. I acknowledge Sandoz, Inc., for providing the Thuricide 32B.

Future Research

An evaluation of Bt at a reduced dosage, e.g. 4 BIU/100 gal., and the budworm Baculoviruses at an earlier timing.

Manuscripts

This report, after appropriate review, will be submitted for publication to a scientific journal.

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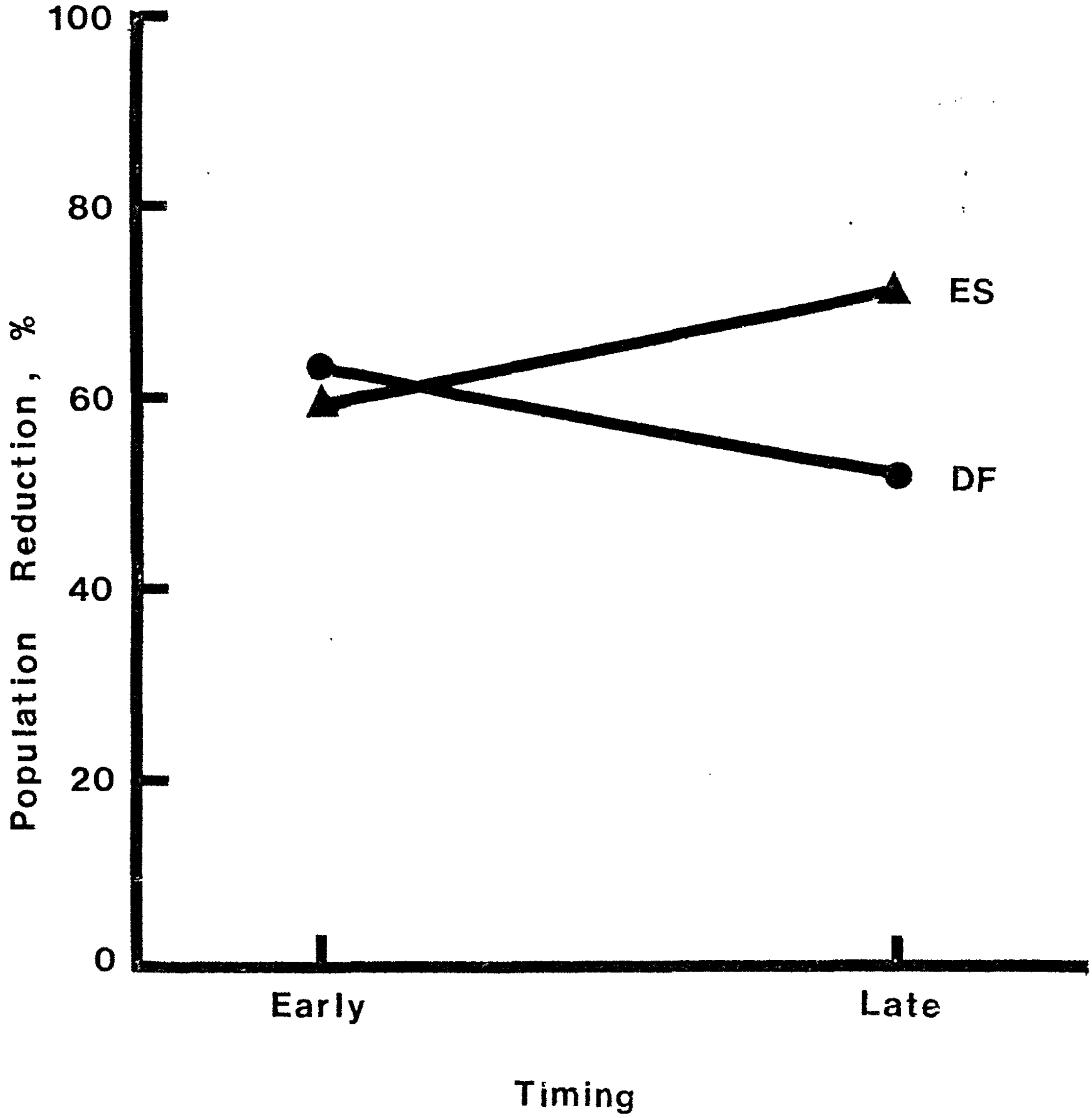

Figure 1.--Specie X time interaction for spruce budworm population reductions (area basis) at Red Cliff Campground ($F = 9.336$; $p \leq .01$).

Table 1. Population reductions and current defoliation on spruce budworm infested trees treated with <u>Bacillus thuringiensis</u> in three campgrounds along the Gallatin River, Mt.

Locality	Host tree[a/]	Dose (BIV/100 gal.)	Prespray density[b/] Buds	Prespray density[b/] Area	14-day Population reduction (%) Buds	14-day Population reduction (%) Area	% Defoliation	95% C.I.
Squaw Creek	DF	0	15.4	127.1	23.5	44.4	52.0	42.6 - 61.4
		16	17.4	135.4	94.7	97.8	11.9	8.0 - 15.8
		32	11.2	101.9	99.8	97.8	6.2	2.8 - 9.5
Swan Creek	ES	0	5.4	37.2	38.1	38.8	13.2	7.8 - 18.5
		16	6.3	46.3	85.8	82.8	3.3	2.0 - 4.6
		32	5.9	41.6	86.7	86.9	3.2	1.4 - 4.9
Red Cliff								
Early	DF	0	17.3	145.2	6.2	25.7	76.0	69.5 - 82.6
	DF	32	17.4	129.8	98.3	98.6	12.0	7.6 - 16.3
	ES	0	33.1	194.0	33.4	27.6	73.9	66.8 - 81.0
	ES	32	23.6	163.9	91.7	90.8	24.8	15.6 - 34.1
Late	DF	0	17.6	105.4	14.0	7.0	74.8	64.4 - 85.1
	DF	32	15.3	89.3	97.8	97.2	22.1	10.1 - 34.0
	ES	0	20.6	201.5	33.1	48.2	68.1	57.3 - 78.9
	ES	32	22.4	189.3	93.2	95.0	39.2	30.7 - 47.7

a/ DF = Douglas-fir; ES = Engelmann spruce
b/ Buds = Number of budworm larvae/100 buds or current shoots; Area = Number of budworm larvae/1,000 in^2 branch area

Table 2. Summary of F values resulting from analysis of variance of spruce budworm mortality and defoliation data following ground applications of *B. thuringiensis*.

Locality	Contrast	Prespray density[a/] Buds	Prespray density[a/] Area	14-day Population reduction (%) Buds	14-day Population reduction (%) Area	Defoliation percent
Squaw Creek	Check vs. Treatment	0.344	0.181	382.625**	145.066**	165.866**
	16 BIU vs. 32 BIU	7.852**	2.086	0.855	.005	2.221
Swan Creek	Check vs. Treatment	0.444	0.725	50.110**	40.205**	30.307**
	16 BIU vs. 32 BIU	0.093	0.266	0.010	0.244	.007
Red Cliff	Specie	17.814**	18.841**	.268	.318	1.378
	Dose	1.732	1.325	582.109**	411.961**	288.390**
	Timing	4.190*	0.542	2.996	.430	2.450
	Specie X Dose	0.507	0.031	17.958**	14.541**	11.893**
	Specie X Timing	2.533	3.116	.126	6.277**	.069
	Dose X Timing	1.395	0.074	1.344	.002	7.545**
	Specie X Dose X Timing	3.254	0.082	.020	.735	.544

a/ Buds = Number of budworm larvae/100 buds or current shoots
Tree = Number of budworm larvae/1,000 in.^{2} branch area
Bud and Area densities computed on identical branch samples.

* = Significant at 0.05 level
** = Significant at 0.01 level